SOME EXPERIMENTS IN HIGH-SCHOOL INSTRUCTION

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Directors of schools of education have always insisted that the high schools themselves are to be the great laboratories in which are to be worked out the intricate and difficult problems of secondary education.

Public-school men, however, are slow to look upon themselves as experimenters, or to consider the public-school buildings as clinics in which the pupils are subjects for experimentation.

This hesitation is justifiable, too, for are not school administrators hired to *operate* a system established at an enormous expense for the benefit of millions of children? The experimenter in education, with his subject, or the training-school director with his small group of children, may perform his experiments *ad libitum.* If the experiments go wrong, it is well, for an error discovered is one step in the evaluation of truth, and the catastrophe that ensues causes no commotion in educational circles. But let the same experimenter adjust improperly his educational wrench to the elaborate machinery set up in the so-called public laboratories, and a roar will mount to high heaven.

This, however, only proves that our experimenter must be possessed of skill and the experiments be so conducted as to eliminate wholesale catastrophe in case of maladjustment; in other words, the trained supervisor must localize and definitize his operations. He will not attempt to experiment upon a curriculum or upon a school, but upon a subject in a curriculum, and upon a small group of pupils within the subject.

Unless we are to assume that educational progress is at variance with the basic laws of advancement in all other human activities which hold that truth is evaluated from error, organization evolved out of confusion, and progress attained by the spiral route of retreat and forward march, we school men will have to consent to do some-

thing more than *operate* a system. It may become our business to break the system in parts, even at the expense of breaking our own heads on the rocks of incrusted tradition.

Acting on this theory, that experiments under proper limitations are justifiable within public-school buildings, the following experiment in the teaching of elementary science in the Wichita High School is here described.

REASONS FOR UNDERTAKING THE EXPERIMENT

Two years ago the traditional course in physical geography was displaced by a course in elementary science. The reason for abandoning the physical geography lay in the conviction that the course was too bookish and that the accompanying laboratory work was too repetitious and meaningless. Higgins' *First Book in Science* was used, and although the book may be as good as any on the market for such a course, the results at the end of the year were far from satisfactory. The Freshmen had dipped a little into physical and biological sciences, but there was no real training in science.

This year the instructor was told to write his own course, which he had printed on sixty-five lesson leaves. These lesson leaves were handed out to the pupils one at a time. At the bottom of the leaves were a few suggestive questions. There was no claim that the instructor had written a better lesson than some of our standard authors, indeed not as good, but it was a lesson that he could teach better, because it was his *own* and he had included only such material as he deemed important.

REASONS FOR USE OF THE LESSON LEAVES

In brief, the reasons for this method of assignment may be stated as follows: (1) to focalize attention on a few central facts and principles; (2) to encourage the pupils to think upon the short assignment of principles rather than to memorize textbook content. Elaboration and detail were to *follow* rather than precede or accompany the statement of principles; (3) to afford time for assimilation and application by cutting down the amount of content to be recited upon.

Lesson 61. "Forces"

All changes in the physical world depend upon matter and energy. By matter is meant anything which occupies space, and by energy is meant any agent which produces or tends to produce a change. Any agent which produces a change in any portion of matter must exert some force on that matter. Force may be defined then as the sole cause of motion. In simple language a force is a push or pull.

The force which is the most real and the best known to us is muscular force. Other forms of force are the force of gravity, mechanical forces, molecular forces, electrical and magnetic forces.

When a person lifts a weight, the force that raised the weight is a muscular force, but the force that he is acting against is the force of gravity. The force of gravity is a universal force, i.e., it acts between all objects in the universe and it acts all of the time. The force of gravity is always a pull, not a push. The best examples of mechanical forces are seen in their applications, the steam and gas engines. Another example of this is the breaking of water pipes in cold weather caused by the freezing of the water. A mechanical force is any force exerted by one object on another, caused by the expansion or the contraction of the object.

Molecular forces are those forces acting only between molecules and at very short distance. The distance through which a molecular force will act is less than 1–1000 of the thickness of a pin point. If this force acts between like molecules, such as two molecules of sugar, it is called the force of "cohesion." If this force acts between unlike molecules, such as one of sugar and one of water, it is called "adhesion." Molecular forces are always forces of attraction. Water is drawn up in plants by the molecular forces. If a stem of a leaf is placed in red ink, the veins in the leaf will soon become of a red color. A towel left with one end in a dish of water and the other on the table will transfer the water from the dish to the table in a short time. The last two phenomena are called "capillary attraction" but they are caused by molecular forces.

If a body is charged with electricity and is then brought near another body it will exert a force on the other body. This is shown by rubbing a piece of hard rubber on flannel and then touching it to pieces of paper. If two bodies are thus charged they will repel (push apart) each other. This shows that electrical forces may exert either a push or a pull.

If two magnets are brought near each other they will either repel or attract each other showing the twofold character of magnetic forces. Magnetic forces are natural forces as are all the rest, and many natural magnets, called lodestones, are found in Asia Minor.

QUESTIONS FOR REFERENCE WORK

1. Why does any object have weight?
2. Why does a stone fall to the ground after being thrown upward?

3. Why does the moon keep up with the earth on its way around the sun?
4. Define the force of gravity.
5. If the sun has an attraction for you, why do you stay on the earth?
6. Why does water stick to glass when mercury does not?
7. What holds pieces of iron together by welding?
8. Why must iron be heated before it can be welded?
9. Why can lead, wax, etc., be welded without heating?
10. Why is iron more tenacious than wood?
11. Why would you expect solid (frozen) mercury to be tenacious?

These lesson leaves were filed in a loose-leaf notebook together with the notes, drawings, and description of the experiments performed in connection with the lesson.

The instructor was inexperienced and undertook this method of treatment at the suggestion of his principal, but was in perfect sympathy with the plan. At first he was under the impression that he must cover a lesson a day, thereby defeating the very object of the experiment, viz., to take enough time to develop thought work in science. He soon, however, grasped the point of view that he was to stay on a lesson until the pupils had "warmed to it," even if he covered, during the semester, only half of the lesson leaves.

The pupils in this class were Freshmen, and had had no nature-study or science in the grades. The average age of the girls was 15.6 and of the boys 15.7. The course ran for one-half year and was elective.

This much for the history, purpose, and method of the experiment. Next follows a stenographic report of a day's work upon the barometer. The stenographer was sent into the room without warning to the teacher, and the following account is a verbatim report. Two things will be noted: first, the informal and problem method of treatment; second, the absolute requirement of the teacher that the pupils express themselves in sentences. A sentence is a statement of thought; therefore how can beginners think clearly in science unless they habitually express themselves in sentences?

This particular lesson herein reported had been preceded by two other lessons on the barometer. The class knew how the barometer was constructed; that air had weight; that atmospheric pressure held up the barometric column; and why. They had also previously studied the component gases of the atmosphere,

knew each gas had an atomic weight, and knew that atomic weights were stated in relative terms.

LESSON. FOURTH PERIOD CLASS. ELEMENTARY SCIENCE, MARCH 12, 1913

MR. SCHELL, *Teacher*

Teacher: We wish today to discover how the barometer is used to indicate a change in the weather. You probably all know that it is so used, but possibly some of you can tell just how. For instance, we say that the change in the weather is indicated by the rising and falling of the mercury column of the barometer. Now, I don't wish you to learn that fair weather makes it rise or fall, as the case may be, but I wish you to know what makes the barometer rise or fall and what relation that has to the weather. To answer that question, we shall have first to determine which is heavier, dry air or damp air. I shall not tell you, but how many think damp air is heavier than light air? (Every hand went up.) Well, we shall make it our business to find out.

Teacher: Don, suppose you and I were going to take a trip in a balloon, and we wanted to take some statistics on certain phenomena of the atmosphere, what instruments would we take along?

Don: We would have to take along a barometer.

Teacher: What would be the use of taking along a barometer?

Don: We could tell how high we went, what the pressure of the atmosphere was, and how high we were.

Teacher: Explain that.

Don: The higher we went, the barometer would go down. There wouldn't be as much pressure because the air wouldn't be as heavy.

Teacher: Then it is the atmospheric pressure which causes the barometer to go up and down the number of millimeters. Suppose we start our balloon trip at sea-level, what will be the reading of the barometer at sea-level, John?

John: It will be 30 inches.

Teacher: Just what do you mean by that 30 inches? Can you explain? How could we measure the 30 inches on this barometer? It would be from what point to what point?

John: From the bottom of the barometer.

Teacher: What do you mean by the bottom of the barometer? Measure from here? (Indicating.)

John: I don't know about that one. I was thinking about one that would come down straight.

Teacher: This is just like the straight barometer.

John: You measure from the bowl.

Teacher: (Drawing diagram on blackboard.) We see the mercury is up to here. From what point would I measure this 30 inches?

John: From the top of the mercury.

Teacher: Now we haven't had that, but John reasoned it out. I would measure up here and find the point here, and the distance up here would be 30 inches at sea-level. Suppose we go up to a height of about 16,000 feet above sea-level; what do you suppose would be the reading there?

Pupil: About 18 inches.

Teacher: And how do we account for that difference? Of course it will go down in this case to about 18 inches (marking on diagram).

Pupil: The air the higher up you go is lighter and not so much pressure. It is the pressure that keeps the mercury up there, and there not being so much pressure on it, it won't be up so high.

Teacher: That is right. What becomes of this mercury we have lost from 30 inches to 18 inches, William?

William: When the mercury goes down in the tube, it goes down in the bowl. It is supposed to be big enough to hold all the mercury in the basin.

Teacher: Can't you make it a little more definite?

William: When the mercury falls from 30 inches to 18 inches in the tube, it will go down in the basin.

Teacher: What will?

William: The mercury.

Teacher: Try it again.

William: When the mercury falls from 30 inches to 18 inches in a barometer, the mercury goes down into the basin.

Wayne: If the mercury goes down in the basin, that raises the level of the mercury and then you would measure from a different point.

Teacher: You see this attachment here? I will explain that later. When I am measuring this, there is a screw that comes right to the surface. This screw forces this plate up. You get this needle exactly on top of the mercury and you get your readings equal. I will explain this more fully later. So the barometer is an instrument used to measure atmospheric weight and pressure. We shall now get to our original question? How are we going to tell the effects of the weather by this barometer? I want to get just one fact we will have to know before we can tell these weather conditions. What is that, Margaret?

Margaret: Before you can tell the weather conditions, you want to know which is heavier, dry air or damp air.

Teacher: In what way would we go about to tell whether damp air was heavier than dry air, Clarence?

Clarence: I don't know.

Teacher: We had it yesterday. Jack Stewart.

Jack: We take the cylinder that holds 20 ounces.

Teacher: No. What would you say we use, William?

William: Cubic inches; we fill that with some kind of gas.

Teacher: Suppose we take this cylinder here (indicating). Does it have anything in it?

William: Air.

Teacher: Suppose you wanted to take the gases in there, just take the two important gases; what would they be?

William: Nitrogen and oxygen are the two important gases in there.

Teacher: Continue your discussion.

William: Weigh the jar containing nitrogen and oxygen or the ordinary atmosphere. Now run in some steam or water vapor, and then weigh the jar again. The jar would now be lighter.

Teacher: That would be one proof. Suppose you didn't have a way to weigh these gases?

William: You could figure it out by the atomic weight of the gases.

Teacher: Explain how you would go at that.

William: Both the nitrogen and oxygen have a molecular weight of a little over 28.8.

Teacher: Answer this first. What is an atom?

Pupil: An atom is the smallest division of matter.

Teacher: It might be defined in that way. Give another definition.

Francis: An atom is a part of a molecule.

Teacher: What can we say about the atom, William, in relation to weight?

William: One atom of hydrogen equals "1," and atoms of different gases are measured in relation to hydrogen.

Teacher: Do you suppose it would be possible, Frank, to measure the weight of one atom?

Frank: No sir, it would not.

Teacher: Why not?

Frank: Because it would be too small.

Teacher: It would be too small. Molecules are very small, and when you come to know that molecules are made up of atoms, you can see how small atoms are. We say a hydrogen atom equals "1." We can find the weight of the others in relative terms. How is it I find nitrogen atoms and oxygen atoms in the air?

Dorothy: The air contains much oxygen and nitrogen. It is made up of oxygen and nitrogen.

Teacher: What part of it is nitrogen and oxygen?

Dorothy: There is nearly 80 per cent of nitrogen in the air and about 20 per cent of oxygen.

Teacher: Those are the percentages, but suppose I wanted to divide that gas. Suppose I take oxygen gas and want to divide the gas. What am I going to divide it into? What are the parts? What are the names of the parts I want when I perform this division?

William: You can measure the atom.

Teacher: The atom would be a part then, would it?

William: Yes.

Teacher: How do we find this nitrogen gas and oxygen gas in the air?

William: You find it in molecules composed of two atoms.

Teacher: Make a definite statement about nitrogen and oxygen, William.

William: I don't understand what you mean.

Teacher: Make a definite statement of what you said.

William: We find nitrogen and oxygen composed of two atoms in each molecule in the atmosphere.

Teacher: So I can write it like this—N_2O_2. Those atoms have such a great affinity for themselves, they go in pairs. Sometimes we find oxygen in three atoms. In a case like that, we have what, Lloyd?

Lloyd: Ozone. We have three atoms of oxygen to form ozone.

Teacher: What is the difference between oxygen and ozone, Clarence?

Clarence: Ozone is a form of oxygen. There isn't very much difference between them.

Teacher: A good deal of difference. What is the formula for oxygen?

Clarence: O_2.

Teacher: Walter?

Walter: O.

Teacher: What about it?

Walter: O is the formula for oxygen.

Teacher: What is the formula for ozone?

Walter: OH.

Teacher: You aren't thinking; we just took that up. If O is the formula for oxygen, what is the formula for ozone?

Walter: Ozone is composed of three atoms.

Teacher: Three atoms of what?

Walter: Oxygen.

Teacher: Hou would you write it?

Walter: O_3.

Teacher: What is the difference between O and O_3? You can see from the formula what the difference is.

Francis: There is three times as much.

Teacher: Make the statement.

Francis: The difference between ozone and oxygen is there is three times as much oxygen as ozone.

Teacher: What description shall we give to ozone to show what form of oxygen it is?

Mary: Ozone is a concentrated form of oxygen gas.

Teacher: We have these two together: nitrogen and oxygen, N_2O_2, and William has said 28 was the molecular weight. What is the formula of aqueous water or water gas, Ruby?

Ruby: H_2O.

Teacher: What is the formula for ice?

Ruby: H_2O, I suppose.

Teacher: Have you changed it any?

Ruby: No; only as to form.

Teacher: What is the formula for liquid water?

Ruby: H_2O.

Teacher: What would be the molecular weight of H_2O or common water-vapor gas, Victor?

Victor: It would be 18.

Teacher: How did you get it?

Victor: The molecular weight of water vapor would be 18.

Teacher: How do you get it?

Victor: One atom of hydrogen is the standard weight; then there are two atoms of that and the oxygen weighs 16 times the weight of the hydrogen.

Teacher: How much oxygen weighs 16 times as much? You didn't take any unit.

Victor: One atom of oxygen weighs 16 times one atom of hydrogen.

Teacher: Then you have 2 plus 16 equals 18. I want someone to tell me now the reason. We know, as Dorothy has given us, air is composed of four-fifths nitrogen and one-fifth oxygen. Suppose I take one-fifth part of water gas and put in this cylinder; explain the phenomena. What is going to happen, Arch?

Arch: The water gas will be bound to force some of the other gases out and leave one-fifth water vapor.

Teacher: How do you know that?

Arch: Because you can't put more—when anything is full, some of the gas has to be forced out if you force some other gas or vapor in there.

Teacher: Yes, that is the point. It is one of the fundamental laws of science and Arch has given it in his own words. If I have 20 cubic inches of gas in here, no matter what kind, I can't have any more than 20 cubic inches. You can have just so much gas in a certain space, according to volume, and that is all you can have. I take and place in here water vapor. What is going to be the effect? Suppose I have another cylinder. I say I keep this cylinder and have it full of regulation air, N_2O_2 and the molecular[1] weight is 28. I take another cylinder and take out this one-fifth of air and substitute water vapor for the air. What is going to happen as to the relative weights, Ione?

Ione: The last one will weigh less on account of the water gas being in there.

Teacher: Make your statement again.

Ione: The cylinder which contains water vapor will not weigh as much because the water vapor gas doesn't weigh as much as N_2O_2.

Teacher: You mean to say that this cylinder here does not contain any gas?

[1] The teacher recognizes that it would not be allowable for a chemistry pupil to say—"the molecular weight of air, air being a mixture"; but it was thought best not to be too technical with Freshmen.

Pupil: Yes it does.

Teacher: Talk about some gas then. What are you going to have in this cylinder? What three gases? Johnnie, what are you going to have?

Johnnie: Nitrogen, oxygen, and water vapor will be in there.

Teacher: Now explain, Ione. In this cylinder I have taken out a part of the nitrogen and oxygen and forced in some water vapor. I want a statement about the relative weights.

Ione: The relative weights would be ———

Teacher: Aliff, you give that.

Aliff: The jar containing the nitrogen and the oxygen and the water vapor would weigh less than the other jar.

Teacher: That is all right. Now, why?

Aliff: The water vapor isn't as heavy as the atmosphere.

Ione: The one with the water vapor and the nitrogen and oxygen wouldn't weigh as much as the other because the water vapor doesn't weigh as much as the nitrogen and oxygen.

Teacher: Yes; we are going to have a difference of 10 in the molecular weight if we put this water vapor in. What does this experiment prove, Newton?

Newton: This experiment proves that air has weight.

Teacher: Is that what it proves to you? What do you think about it, Susie?

Susie: It proves that dry air is heavier than wet air.

Teacher: We don't call it wet air; we use another term.

Susie: Damp air.

Teacher: We had several pupils last term whom I worked with a week before they would give up. If there are any here who don't see it, I would be glad to take it up with them. We have shown what here, Newton? (Newton is a colored boy and one of the slowest in the class.)

Newton: We have shown damp air weighs less than dry air.

Teacher: We come to this question: What effect has that on the barometer? You have heard people say, "the barometer has gone down today," "the barometer has gone up today." What does that indicate in regard to weather? What do you think about that, Bess? I will help you out just a little. Yesterday the barometer read 28.91 inches over here on this vernier. On this vernier it read 744 millimeters. You remember the condition yesterday; we had a good deal of sun and it was a nice, bright day. Now, today it is cloudy, we probably have a good deal of water vapor in the atmosphere. Can you see any connection between these two forms of weather and the barometer?

Bess: The barometer would go down because the air is damp today.

Teacher: Why would the barometer go down?

Bess: The damp air doesn't weigh as much.

Teacher: How do you know the damp air doesn't weigh as much?

Bess: Because the molecular weight of H_2O is less than the molecular weight of atmosphere or N_2O_2.

Teacher: Then if that is true, why does the mercury column fall?

Bess: Because there isn't enough pressure in the damp air to hold the mercury up to where it was yesterday.

Teacher: Fine. That is correct.

Teacher: Montie, you come and read this barometer. This plate (indicating) is movable. We have to have the screw at the top of the mercury. Here you will find millimeters and here inches. How many inches do you have, Montie?

Montie: We have 28 inches.

Teacher: In reading this vernier, read to get tenths and hundredths.

Montie: It reads 28.67 inches.

Teacher: Is there any difference in the reading from yesterday and today? What is the difference, Newton?

Newton: The difference is 0.24 inches.

Teacher: How did you get it, Newton?

Newton: By subtracting 28.67, the reading of today, from 28.91, the reading of yesterday.

Teacher: What does that show?

Newton: That the barometer has fallen 0.24 inches.

Teacher: What does that show about the weight of the air?

Newton: It shows damp air is lighter than dry air.

Teacher: Why, Newton?

Newton: Because the mercury column has fallen 0.24 inches.

Teacher: But why has it fallen?

Newton: It has fallen because the air wasn't heavy enough to hold it up to 28.91, where it was yesterday.

Teacher: Good! That is what we have worked two days to show.

SUBSEQUENT ASSIMILATIVE TESTS UPON THE LESSON OF MARCH 12

It becomes necessary to explain what is meant by an *assimilative* test. An assimilative test is one that ascertains what knowledge has become one's *own* rather than what content can be *remembered* of someone else's knowledge. The ordinary tests given in the high schools are of the latter type. Assimilative tests necessitate a sufficient interval for forgetting and exclude antecedent reviewing and cramming. Teachers do not like to give assimilative tests because the *showing* is not good. Yet it is submitted that everyday adult life is necessarily a series of assimilative tests or the using of the knowledge and power that one has made his own.

Some eight weeks subsequent to the recitation herein recorded, the principal, without warning, went into this particular class in elementary science and asked them to write on the following question: "The barometer read yesterday 29.63. Today it reads 29.47. You also remember that yesterday was a clear day and that today it is cloudy. Does this show that the air is heavier or lighter than yesterday, and why?"

The following is a tabulation of the results of the written test:

No. in Class	No. Answering "Lighter"	No. Answering "Heavier"	Percentage Correct	No. Giving Good Reasons	No. Giving Incomplete Reasons	Percentage Correct
26	25	1	96	19	7	89

Here follow some of the answers received which were checked as complete.

William Mc.: The air today is lighter than it was yesterday because of the water vapor in the air. The molecular weight of air is 28.8 and that of water vapor (H_2O) approximately 18. Yesterday there was not much water vapor in the air, consequently the air was heavier. Today we have water vapor, or a lighter gas, in place of some of the heavier air.

If a jar is left open without anything but air in it, the molecular weight of its contents is 28.8. If steam or water vapor was run into this jar at the top, it would push some of the air out and would take its place. The weight of the resulting mixture would be lighter.

Margaret D.: The air is lighter today than it was yesterday because there is more water vapor in the atmosphere today. Water-vapor gas is lighter than air because H_2O has a molecular weight of 18 and N_2O_2, or atmosphere, of 28.8. This makes water vapor lighter. When we measure air we measure the different gases which are contained in the atmosphere and we find that water-vapor gas is lighter than N_2O_2. When air is warm it becomes heavier but when it is cool, it becomes lighter.

Aliff B.: The air was heavier yesterday than today because there is more H_2O in the air today. H_2O is a very light gas. When there is more H_2O in the air in a certain locality, the other gases are pushed back to make room for H_2O. The space that is taken up by the H_2O today was taken up yesterday by the heavier gases. Damp air is heavier than dry air. This causes the mercury in the barometer to fall. That is why the reading is lower today than yesterday.

Ruby G.: The air is lighter than it was yesterday because damp air is lighter than dry air. Yesterday was clear while today is cloudy and the

atmosphere is full of water vapor. One might think that damp air was heavier than dry air, but the molecular weight of H_2O is less than of N_2O_2, or the atmosphere. Therefore on damp days the barometer registers much lower than on dry, clear days. There is not so much pressure on the mercury in the barometer, which makes it register lower.

COMPARATIVE ASSIMILATIVE TESTS ON IDENTICAL AND FOREIGN MATTER

One might be inclined to say that if 90 per cent of an elementary science class, without warning, give complete and correct answers on subject-matter covered two months earlier, that the success of the experiment had been demonstrated. It did not seem, however, to those interested, that the experiment was complete, because we had gathered no comparative data. In order to get this comparative data, the same question was given on the same day to a class in physics consisting of twenty-one Senior girls. This class had studied the barometer as it is treated in physics, and under a teacher more experienced than the teacher of elementary science.

True, this class had had these lessons on the barometer several months prior and were now toward the end of the course, but as stated before, it was the purpose of this exercise to test assimilation rather than memory. The result of the test is here given.

PHYSICS CLASS

No. in Class	No. Answering "Lighter"	No. Answering "Heavier"	Percentage Correct	No. Giving Good Reasons	No. Not Giving Good Reasons	Percentage Reasons Correct
21	4	17	19	2	19	9.5

The following is a typical specimen answer given by most of the girls in the class:

Marian: The air is damper today than yesterday, therefore the air contains more water than it did yesterday. Air has weight; water has weight and it is heavier than air, therefore air which contains more water will weigh the more. Therefore the air today is heavier than the air was yesterday and the barometer fell.

Tabulating the two tests, we are confronted with the following figures:

	No. in Class	Percentage of Right Answers	Percentage of Right Reasons
Freshman elem. science	26	96	89
Senior physics	21	19	9.5

The difference favoring the Freshman science class is surely overwhelming. As far as these tables go, the experimenter was convinced that pupils could be trained to think in the field of science. The exceptional tendency of pupils to really think, unless so trained, is clearly shown in the Senior girls' answers to this question, "Is the air lighter or heavier today?" Granted that their teacher had never pointed out to them that dry air was heavier than damp air (which most people would not assume), they should have known by the barometric readings given them that the pressure had diminished and consequently that the air must have become lighter.

Two conclusions can here be postulated: First, assimilative tests are severer than the usual memory tests of the schools. Such tests are not based on recent matter or matter recently reviewed. They always involve application of principles and test the power to think rather than the power to recall. Second, to develop the power to think takes time. High-school courses should be intensive rather than extensive.

The small percentage of failures in the elementary science class is due mainly to the emphasis laid upon thought processes and the reduction of the content matter of the lesson, giving more time for the development of thinking power.

ASSIMILATIVE TESTS IN MATTER FOREIGN TO THE EXPERIMENT

To demonstrate that the ordinary percentage of failures runs high on an assimilative test, the following tests in Freshman algebra were given in the same school and included many of the elementary science pupils. The tests were given over a period of several non-consecutive days in the seventh month of the school year and were questions involving principles of algebra rather than its mechanics. Several months had intervened between the teaching of the principles and the giving of the tests. All possibility of review or memory-stuffing was eliminated. The questions were:

I. In removing the terms from within a minus parenthesis in the following problem, why do you change the signs? (Do not quote rule but give reason for rule.)

$$a-(b+c-d)$$

II. (*a*) $21n+2=15+8n$ (1)

$21n-8n=15-2$ (2)

Explain how (2) is derived from (1).

(*b*) $2ab=x$

$b=?$

Explain how you find the value of *b*.

III. $\frac{x}{4}+\frac{x-6}{6}-\frac{1-2x}{8}=\frac{55}{8}$ (1)

$6x+4(x-6)-3(1-2x)=3.55$ (2)

Explain how (2) is derived from (1).

IV. $11t+5(2t-1)-3(2+2)$

Check for $t=2$.

V. Find product in two ways where possible:

(*a*) $(8-2)\ (8+2)$

(*b*) $(a-b)\ (a-b)$

TABULATION OF RESULTS

	Possible No. Correct Answers	No. Correct	Percentage Correct
Algebra:			
Teacher 1	205	77	32
" 2	120	72	60
" 3	124	96	78
" 4	115	81	72
" 5	116	86	74
Total	680	412	60.6
Elementary science	26	94	89
Physics	21	19	9.5

Failures of 40 per cent on simple algebraic principles like the foregoing may appear high, but the author of this experiment is firmly convinced through successive exercises of this kind that it will not run much lower in other schools, providing the experimenter makes certain that the test is given under the same conditions, viz., made assimilative in content and manner of testing.

CAN AN ATTITUDE OF MIND BE DEVELOPED?

Granting that the experiment thus far shows that Freshman pupils in a science class conducted on the plan outlined rank well

in an assimilative test, there remains one other question to answer. Did pupils in such a class tend to get an attitude of mind? Could they reason in other sciences as well or better than older pupils not so trained?

The remainder of the experiment is connected with this phase of the question. Six Freshmen who had been over the course in elementary science conducted on the plan herein described, were selected at random one day and without warning, and put into a physiology class made up of Juniors and Seniors. This class was taught by the same teacher. The teacher, according to instructions, took up an entirely different section of the physiology, many lessons in advance. The topic was "The Chemistry of Respiration" (Conn and Buddington, pp. 200–205). He conducted the recitation that day on the same informal plan as he conducted his elementary science classes. A stenographic report of the recitation was taken, but is not given here because of its length. The Freshmen who had been introduced into the class for this day did not know that they would be called in the next day to take a test upon the subject-matter discussed, nor did the regular class know that they would refer to this lesson again, in fact they were assigned for the next day the regular portion of the preceding text. No hint of the coming test was given to either group, so as to eliminate as far as possible the element of memory. The next day the same six Freshmen were re-summoned to the physiology class and the following questions were given for all to write upon:

1. Follow the components of the air breathed into the lungs.
2. Account for the different colors of the blood.
3. What is the function of oxygen in the body?
4. How is the temperature of the body maintained and its energy produced?

Following is a tabulation of the results:

	No. Examined	Average Percentage Attained
Freshmen	6	90
Junior-Senior	6 (best)	87
Junior-Senior	23 (remainder)	73.6

A few of the answers here follow:

JOHN J. (Freshman), Grade, 95 per cent (one of the best students in the class):

1. When air is taken into the lungs the different components are oxygen, nitrogen, hydrogen, and all the elements. Oxygen is taken up by the blood and carried through the body. Nitrogen goes into the lungs with the oxygen and comes out with the waste matter or the burnt-up tissue.

2. When the oxygen enters the blood it turns to a scarlet because it is pure or does not contain any waste matter and when the blood is returning, it is blue because it is loaded with the refuse of the burned-down tissue.

3. Oxygen unites with the haemoglobin of the red corpuscles and burns carbon in the cells, which forms heat. The purpose of the oxygen is to burn up waste matter.

4. The temperature of the body is maintained by the continual burning of the oxygen in the tissues. The energy produced is heat energy which goes to produce muscular energy.

ROMEYN W. (Junior), Grade, 90 per cent:

1. When air is taken into the lungs the oxygen in the air is taken up by the haemoglobin in the blood. The nitrogen remains the same and comes back to the lungs and is exhaled.

2. Blood containing oxygen is a bright scarlet and blood containing CO_2 is a bluish-red. The scarlet blood is loaded with new material and the bluish-red is loaded with waste material.

3. Oxygen unites with the carbon in the tissues to build up the body.

4. The temperature of the body is maintained by the oxidization of the tissues of the body and heat is liberated for energy.

SELDEN K. (Freshman), Grade, 60 per cent:

1. The haemoglobin takes up the oxygen and the lungs hold the nitrogen.

2. The oxygen affects the color of the corpuscles in the blood and makes the blood bright scarlet. The oxygen makes them bright red but when it has carbon dioxide or waste, it becomes blue.

3. Oxygen unites with the carbon of the tissue for the purpose of burning the tissues of the body to get the waste matter out of the way.

4. The temperature of the body is kept up by the burning of the tissues and the energy of the body comes from the heat.

CONCLUSION

Our experiment is now concluded. Summarized, our aim was to teach science to Freshmen in such a way as to develop thought power and to secure if possible, a liking for science. The method was informal. Questions were put by the teacher and answered by the pupils always in sentence form. Accuracy and clearness

were insisted upon. The pupil must stick to the *problem* until he had solved it and knew that he had solved it. Lessons were supplemented with experiments performed for the most part by the teacher. These experiments were written up and subject to explanation by the pupil at any time on demand. No definite number of lessons had to be covered. Sixty-five were written, embracing important topics in physics, chemistry, and biology, and about fifty were covered. The tabulation of statistics on comparative tests shows:

First, That in an assimilative test in elementary science, about 90 per cent of the pupils were correct in their answers. It is not believed that memory was the important element in the test as every precaution was taken to eliminate it.

Second, In a similar test given to a Senior physics class, only 10 per cent were correct.

Third, In an assimilative test upon Freshman algebraic principles about 60 per cent were correct.

Fourth, In ability to comprehend and assimilate a new topic in science, six Freshmen, selected at random from the elementary science class, trained for one semester under the plan outlined, were compared with a class of Juniors and Seniors taking physiology, and it was found that the Freshmen were superior to the upper classmen.

The foregoing conclusions while not fully substantiated at least convince the author of the experiment, first, that all knowledge, to be of possessory character, must be *assimilated* or *made one's own;* and second, that this assimilative stage can best be reached through the informal problem method of the classroom and as exemplified in the experiment herein set forth.

The truth of these two statements seems to be incorporated by Professor Moore of Yale in a recent number of the *School Review*, in his splendid article, "Improvement in Educational Practice":

First, Knowledge is no ready-made outside thing which by any conceivable legerdemain can be put inside the mind; on the other hand, the mind is not so constituted that it can take strength by being exercised on the forms of knowledge. To make knowledge, the student must do as its original discoverer did; he must rethink it, remake it. It makes no difference what Moses thought or Plato thought or Euclid thought, until I think their thoughts for myself as my own. Science, history, literature, mathematics, all must be born anew in the mind of each student who studies them.

Second, If we employ the method of casting all that we would teach into the form of problems and of provoking our students to do the same, much is gained in making teaching a co-operative undertaking in finding; the mind is challenged, attention is focalized, work becomes definite and has an understandable purpose; searching is made necessary, valuing or selecting becomes the order of the day; what is found out and thought out is organized with reference to the problem, each student shapes and offers his contribution in his own words, and above all, each is thinking for himself upon matters of common interest, which is the only valuable training of individuality.

The title of this paper was styled: "Some Experiments in High-School Instruction," and its author intended to give a brief account of one or two applications of high-school instruction in departments other than science organized on the problem-solving basis—but time does not permit.

For instance, in civics, we have localized our work until we now have in pamphlet form the important problems connected with the history and development of our city. This is putting civics into concrete and tangible form. In history, we have discovered that the work must be intensified and problemized.

The underlying principle involved in all this is the conviction that high-school instruction must be intensified rather than extensified, or problemized rather than topicized. In the recent number of *History Teachers' Magazine*, Professor Sellery of the University of Wisconsin says: "In the assignment do not give a number of topics pupils are to concentrate attention upon, but a number of questions they are to answer. This trains judgment in the very process of acquiring the facts of a textbook."

For two days the pupils in the elementary science class had the problem, "How does the barometer indicate weather changes?" How this method of attack promoted the assimilation or the remaking of knowledge for each pupil has been described. We hold with Professor Moore, finally, that the prime object of education "is to make people use their minds, and if they are constrained to use their minds, they will inevitably use them on the greatest concerns of life—morality, citizenship, culture, and productive activity. Or, if education seeks first the knowledge of the spirit, all things else may be added unto it."